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COMPLETE SPECIFICATION

Improvements in a Gas Turbine Plant operating on the Open System, for delivering a Large Useful Power of Short Duration

We, SVENSKA TURBINFABRIKS AKTIEBOLAGET LJUNGSTRÖM, of Finspong, Sweden, a company organized under the laws of Sweden, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

In certain industrial power networks as well as in larger power networks there is often a need of large powers during a comparatively short time. As the power engines and the power network have to be dimensioned to suit the maximum output, the cost as reckoned per amount of power will be very high in respect of the so-called peak power. Often the power is needed as mechanical power for the operation, for instance, of intermittently working machine tools, lifts, pumps, experimental plants and the like, but also intermittently working furnaces, welding machines or the like often need large powers of short duration.

In such countries in which the water power is of small importance, it is usual practice to let the power stations having the best efficiencies take care of the basic load, power plants of lower costs of erection and larger consumption of fuel being brought into operation when the large powers during the peak load time are required. Where water power is available, though not in a sufficient degree for taking care of the whole annual need, the water power usually delivers the peak power, while thermic power plants of high efficiency take care of the basic load, so that the outflow of water does not exceed the supply available. In case of certain peak loads, however, it is usually more economic to use inexpensive, thermic peak power plants requiring a relatively high fuel consumption. A method experienced especially in France comprises erecting special pump power plants including highly situated water reservoirs for storing power produced by the economical, thermic basic power plants which during certain times of the year or the day cannot be fully utilized. This stored power as delivered by the pump power plant may be utilized according to need, that is to say, at peak load operation or at periods of shortage of water. In case of comparatively small amounts of power also steam accumulators have been used to a certain extent for storing power in connection with steam power plants.

In countries where there is ample water power available and the major portion of the power consumption in the country is produced by water power, it has, nevertheless, proved economic to erect thermic power plants for co-operation with water power plants, both as reserve plants and for load equalization. Hitherto, as a rule, steam power plants have been used in such cases, the heat consumption of which amounts according to the cost of erection to between 2,500–3,500 kcal/kWh. in respect of basic power plants, while in respect of reserve power plants and peak power plants for very short periods of operation it may be economic to use power stations which from the efficiency point of view are very simple, requiring a heat consumption of up to 4,500 kcal/kWh. In Switzerland also thermic power plants with gas turbines have been used both as basic power plants for supplying power during dry seasons and as mere reserve power plants, where the time of operation thereof is, normally, very short. The heat consumed by such reserve power plants in dry seasons amounts to about 3,500 kcal/kWh. and in case of reserve power plants for very short periods of operation to 4,500–5,000 kcal/kWh.

The present invention relates to a gas turbine plant operating on the open system, for delivering a large useful amount of power of short duration, thereby enabling storage of inexpensive power which may be produced during such periods, as are most suitable with respect to the existing power producing

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system, with the use of a simple and inexpensive thermic plant which, nevertheless, has a fuel consumption considerably below that of already known thermic power producing stations for large outputs. The output of such a turbine unit may be very large, for instance it is possible to obtain up to 50,000 kW. from such a unit during a short period of time.

According to the invention the plant comprises a turbine unit including as main elements a turbine, a combustion chamber and/or a recuperator, and a compressor unit, and is characterized by the fact that said compressor unit comprises one or more compressors separately driven independently of the turbine and one or more accumulators for storing air supplied by the compressor unit which is admitted to the turbine unit according to need, each such accumulator consisting of a chamber connected at its lower portion through a channel with a body of water the level of which is comparatively high as compared with the change of level of the water in the accumulator, said chamber communicating at its top with the compressor and the turbine, so as to allow air to be admitted to or withdrawn from the accumulator with resulting forcing out water from the accumulator or allowing water to enter thereinto.

With a plant according to the invention it is possible in periods of utilizing an existing power producing system to a little extent only, to charge the accumulator with compressed air by means of the compressor. The accumulator should be constructed so as to secure an approximately constant pressure all the time. From said accumulator air is withdrawn during the operating periods to a combustion chamber or a recuperator, from which the resulting driving medium is passed to a conventional gas turbine. From said gas turbine useful power, easy to be regulated, may be obtained. As there is, practically, no inertia in the system the regulation may shift almost instantaneously from stoppage or no-load running to full-load running. The compressor may be very small, since it may be dimensioned to suit a quantity of air considerably below that required by the turbine for yielding its maximum output.

The invention is illustrated in the accompanying drawings in which Fig. 1 is a diagram of one embodiment of the invention and Figs. 2–4 are diagrams of modified embodiments.

With reference to Fig. 1, the numeral 1 indicates an electric motor and 2 is a two-stage compressor including a cooler 3 for air compression. The air compressed is passed to a conduit network having valves 4, 5 and 6. During the air charging periods valves 4 and 6 are open and valve 5 closed, allowing air to be passed through conduit 7 to an accumulator 8 which in the example shown comprises a chamber located on a certain depth with relation to a lake, river or other body of water 9. The accumulator 8 communicates near its bottom through a channel 10 with said body of water 9. When compressed air enters through the conduit 7 connected to the top of the accumulator, water is forced upwards through channel 10. A preferred pressure level is 40–100 metres, and as said pressure level is high with relation to the change in level of the water in the accumulator it is evident that the pressure of the air in the accumulator may be considered as substantially constant.

When it is desired to withdraw useful power from the plant illustrated, valves 6 and 5 should be open. Valve 4 may be open or closed according as the compressor operates during the time of operation of the plant or not. Compressed air is thus supplied to a combustion chamber 11. Liquid fuel is forced by a pump 12 through a conduit 13 via a regulating valve 14 to the combustion chamber. The hot combustion gases produced in chamber 11 is passed to a gas turbine 15 and thence allowed to escape through a discharge conduit 16. The turbine 15 drives a generator 17 or another machine. Valves 5 and 14 are controlled by a speed governor 18.

Assuming, for instance, that the temperature in front of the turbine is 750° C. and that the pressure amounts to 10 atm., that is to say, corresponding to a pressure level of about 95 m. between the level in the accumulator and the level of the body of water 9, the plant needs for each kWh. delivered a supply of power amounting to about 0.8–0.9 kWh. and a supply amounting to between 1,000 and 1,400 kcal. depending on the air cooling and possible preheating of air in front of the combustion chamber.

The plant diagrammatically shown in Fig. 2 differs from that above described with reference to Fig. 1 substantially by the fact only that it is driven by means of accumulated gas from an accumulator instead of by liquid fuel. The plant is adapted for such cases in which blast furnace gases or the like are available. The gas is compressed in a compressor 20 driven by a motor 19 to be then passed through conduit 21 to an accumulator 22 of the type shown in Fig. 1. From said accumulator the gas is withdrawn according to need through a conduit 23 via a valve 24 to a combustion chamber 11. Valves 5 and 24 are controlled by a speed governor 18.

Depending on the period of operation of the plant it may be preferred for economic reasons to operate with the smallest quantity of air possible supplied to the turbine and to obtain temperatures fit for the gas turbine by spraying water into the air or gas in front

of the turbine. By this expedient it is possible to reduce the need of air to 40-60% of the need in case of a plant having no supply of water. In case of plants such as those shown in Figs. 1 and 2, the accumulator should be dimensioned so as to hold a quantity of air amounting to 7-8 kg. air per kWh. supplied. The erection costs for such an accumulator being very high it may be economic to operate with the smallest excess of air possible.

Fig. 3 illustrates another plant in which spraying of water is used. The same reference numerals are used for those elements which are already illustrated in Figs. 1 and 2. The compressed air entering via valve 5 is heated within the combustion chamber 11 at a substantially theoretical mixing ratio by combusting fuel supplied. Water is admitted through conduit 25 via valve 26 and is sprayed into the gas in front of the turbine. Since the quantity of water, the quantity of fuel and the quantity of air are direct functions of the useful power delivered, valves 5, 14 and 26 may be simply controlled by the speed governor 18.

Instead of heat generation in a combustion chamber heat stored in a recuperator may be utilized in the plant. In such a case the quantity of heat supplied need not be proportionate to the power delivered by the plant during the operation periods thereof but may be stored during the charging periods. Fig. 4 illustrates a portion of a plant including a recuperator 27. Said recuperator is filled with a heat resisting material 28 of a high heat capacity. Hot combustion gases are supplied to the recuperator through conduit 35 via valve 29 from a furnace or combustion chamber 30. Fuel is supplied to said furnace or combustion chamber 30 through conduit 31 and air is supplied from a compressor 32 or the like. The hot gases deliver heat to the material 28 contained in the recuperator 27 and escape in a cool state through conduit 33 via valve 34. The recuperator is insulated and dimensioned to resist the pressure existing in the accumulator. It is thus seen that during the charging periods, while valve 5 is closed, the recuperator is held, for instance, under atmospheric pressure. During the periods of operation valves 29 and 34 are closed, air being supplied to the recuperator from the accumulator via valve 5. Via valve 26, which may be controlled by the temperature of the gases in front of turbine 15, water is sprayed into the recuperator in such an amount as to secure a proper temperature in front of the turbine with respect to the material of the turbine blades, that is to say, with the materials hitherto used, about 700-800° C. According as the filling material 28 is getting cool and the temperature of the air leaving the recuperator is falling, the temperature regulator reduces the amount of water injected so that the temperature of the gas in front of the turbine may be maintained constant during the entire period of operation. The heat capacity of the filling material and the air capacity of the pressure vessel should be so proportioned as to correspond to each other. The advantage of using a recuperator is that any kind of fuel may be used, that is to say, also solid fuels.

What we claim is:

1. A gas turbine plant operating on the open system for delivering a large useful power of short duration which comprises a turbine unit including as main elements a turbine, a combustion chamber and/or a recuperator, and a compressor unit, characterized by the fact that said compressor unit comprises one or more compressors separately driven independently of the turbine and one or more accumulators for storing air supplied by the compressor unit which is admitted to the turbine unit according to need, each such accumulator consisting of a chamber connected at its lower portion through a channel with a body of water the level of which is comparatively high as compared with the change of level of the water in the accumulator, said chamber communicating at its top with the compressor and the turbine, so as to allow air to be admitted to or withdraw from the accumulator with resulting forcing out water from the accumulator or allowing water to enter thereinto.

2. A gas turbine plant as claimed in claim 1, characterized by the fact that the plant is provided with an additional accumulator of the kind set forth in claim 1 for the storage of combustible gas supplied by means of a separate electrically driven compressor, said gas being supplied according to need to the turbine unit together with air from the air accumulator.

3. A method of operating a gas turbine plant of the type claimed in claim 1 in which a recuperator is included, characterized by the fact that an amount of heat is stored during the air accumulation period when air is passed into the accumulator in order during the operation period to be delivered to air supplied to the turbine by the accumulator via the recuperator.

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FIG. 1.

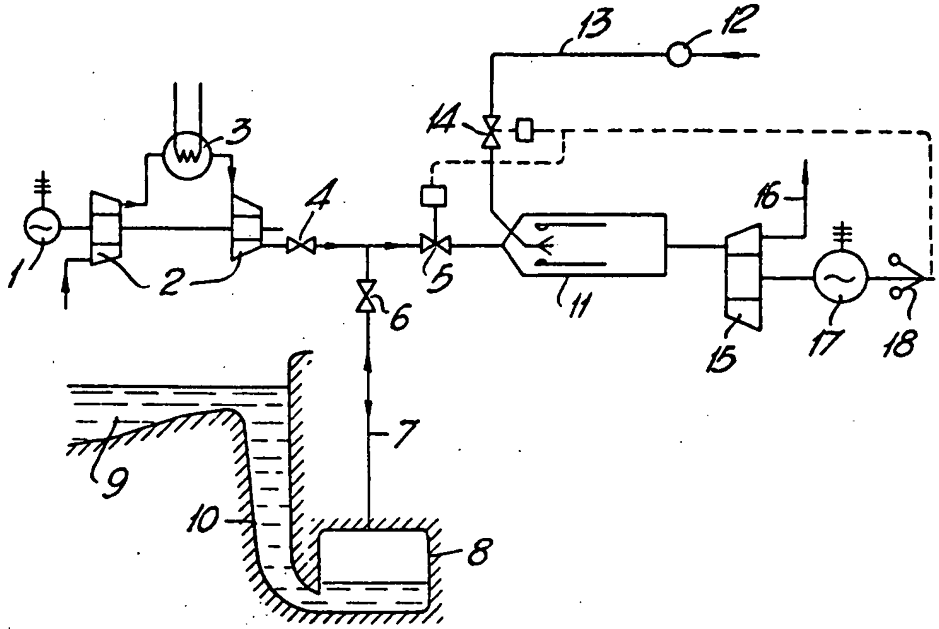
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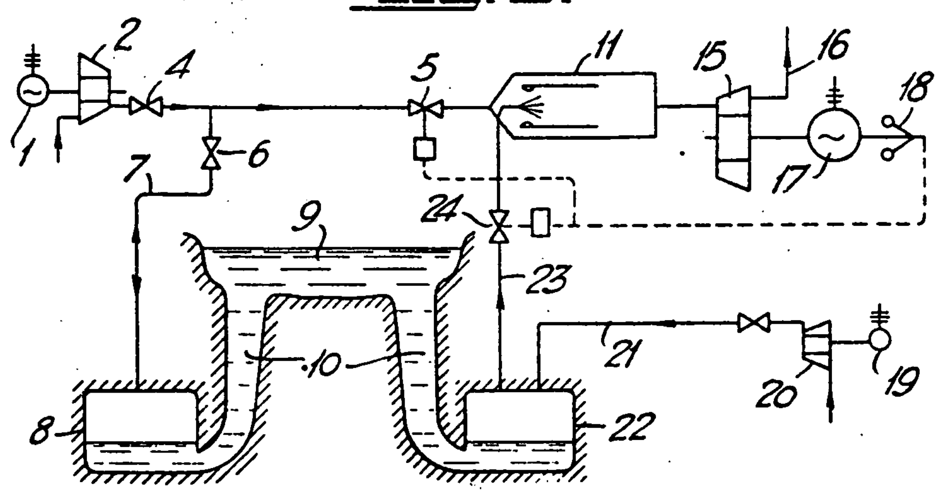
FIG. 2.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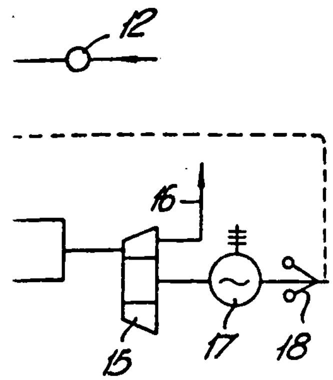
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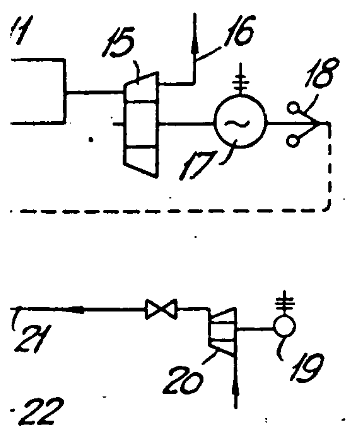
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FIG. 3.

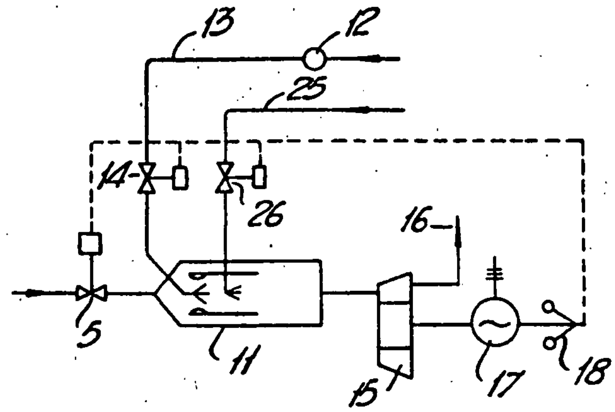
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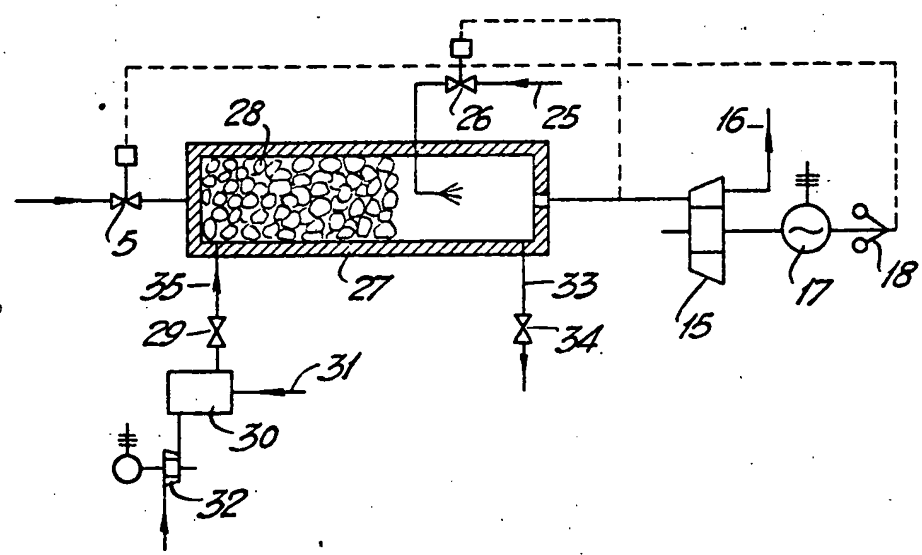
FIG. 4.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